Effectiveness of Portland Pozolana Cement (PPC) in Mitigation Of ASR

Ravi Agarwal, U S Vidyarthi, N Sivakumar

***Abstract*—It is the well known fact that alkali aggregate reactions are one of the predominant causes of concrete deterioration. Alkali Silica Reaction (ASR) is a chemical reaction between the alkalis in Portland cement and certain types of silica minerals present in some aggregates. ASR is very harmful for the concrete structures and reduces the service life of the structures. To retard ASR rate, the process of dilution of alkalis by increasing silica content using Portland Pozzolana Cement or Portland Slag Cement or some mineral additives like fly ash, Micro Silica, Metakaolin, etc., are very effective. The aim of the current study was to determine the effectiveness of Portland Pozzolana Cement (PPC) in mitigation of ASR expansion while used in place of Ordinary Portland Cement (OPC) for the aggregate sample of five different quarries. The outcome of the study is presented in this paper which is effective in controlling ASR**

***Index Terms*— OPC, PPC, ASR, Mortar Bar Method**.

I. INTRODUCTION

ASR is potentially a very disruptive reaction within concrete in which silica reacts with alkalis to form a gel which expands and disrupts its mechanical properties during the service life of the concrete structures, so the investigation of the aggregates is essential, particularly for the hydro power projects, from the ASR point of view as these structures are generally in contact with water.

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II. LITERATURE REVIEW

Portland cement is the main source of the alkalis. Adding fly ash (IS 1489 Part 1, 1991) induces dilution of the alkalis which disrupts ASR. Ensuring sufficient surface area by varying the percentage (BS 3892 Part1) and type of fly ash provides an efficient method to prevent ASR. Small quantities of fine fly ash with low-reactivity aggregates and sufficient alkalis may be more susceptible to ASR, if the pessimum silica alkali ratio is approached. Even when total alkalis within the concrete are as high as 5 kg/m3, fly ash has been found effective in preventing ASR (Alasali and Malhotra, 1991) [1,2]. The addition of fly ash reduces the pH of the pore solution to below 13 which prevents ASR. Researchers have categorized fly ash for usage for arresting ASR (Fournier and Malhotra, 1997). It is however suggested that to restrict ASR fly ash must comply with ASTM C618 (ACI *Manual of Concrete Practice*,1994). Laboratory research [1] and field experience [2] supports that appropriate use of fly ash can prevent expansion due to ASR in concrete. Fly ash from bituminous coal sources (ASTM Class F) which is characterized by relatively low calcium contents (i.e. <10% CaO) is most effective in controlling expansion instead of those obtained from sub-bituminous or lignite coals [3-4]. The inferior performance of fly ash with calcium contents in excess of 25% may be largely ascribed to the pore solution chemistry. Such fly ash is not as effective in reducing the pore solution alkalinity of cement paste systems [5]. Greater proportion of the alkalis is available for ASR in these fly ash [6].

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III. MATERIALS AND METHODS

Aggregates

Coarse aggregate samples have been obtained from five different quarries identified for the project. The project site is located in Uttar Pradesh, India. These coarse aggregate samples have been reduced to crushed sand sizes as per ASTM C1260

Different Type of Cements

Two different types of cements, viz., Ordinary Portland Cement (OPC) and Portland Pozzolana Cement (PPC) have been used with aggregate for studying ASR. Alkali content and Water Cement Ratio of these cements are presented in Table 1.

Table 1: Alkali Content and Water Cement Ratio of the Cements used in the study

Type of Cement	Cement Alkalies (Na_2O) equivalent	Water Cement ratio
OPC-43	0.73	0.45
PPC	0.51	0.45

IV. TEST METHODS OF ASR

Accelerated Mortar-Bar Test (AMBT) as per ASTM C 1260 and ASTM C 1567 is quick, reliable and can characterize the potential reactivity of slow as well as fast reactive aggregates. Aggregates are crushed to sand sizes for mortar-bar expansion test. The mortar bars are stored in 1 N NaOH solution to provide an immediate source of sodium and hydroxyl ions to the bars. Temperature is maintained at 80^{o}C to accelerate the ASR. Comparator readings are taken over a period of 14 and 28 days (Berube et al., 1995; Thomas et al., 1995) [7, 8]. The test conditions are more severe than most field service environments. Aggregate are categorized based on 14 days expansion observation as shown in Table 2

Table 2: Aggregate Categorization based on 14 days expansion

Average Expansion at 14 day	Reactivity
Less than or equal to 0.10%	innocuous
Greater than 0.20 %	Deleterious
Greater than 0.10% but Less than 0.20%	susceptible to reactive

Test Conducted

The study has been carried out using different types of cements. The details of the test and material combination used are presented in Table 3

Table 3: Details of test and materials combinations

Tests	Ingredient Materials
ASR	Aggregate +OPC
ASR	Aggregate +PPC

V. LABORATORY INVESTIGATION AND DISCUSSIONS

The reactivity of these aggregate with different types of cement have been measured by AMBT method [9]. The reactivity of aggregate has been graphically presented in terms of observed expansion in Fig. 1 to 7. Based on 14 days expansion the cement aggregate combination is classified and presented in Table 4.

Table 4: Classification of cement & aggregate combination and its ASR expansion

Quarry	Material Combination	% expansion after 14 days
Quarry -1	Agg.+OPC [Q-1]	0.027
	Agg.+PPC [Q-1']	0.016
Quarry -2	Agg.+OPC [Q-2]	0.025
	Agg.+PPC [Q-2']	0.014
Quarry -3	Agg.+OPC [Q-3]	0.022
	Agg.+PPC [Q-3']	0.020
Quarry -4	Agg.+OPC [Q-4]	0.033
	Agg.+PPC [Q-4']	0.029
Quarry -5	Agg.+OPC [Q-5]	0.031
	Agg.+PPC [Q-5']	0.027

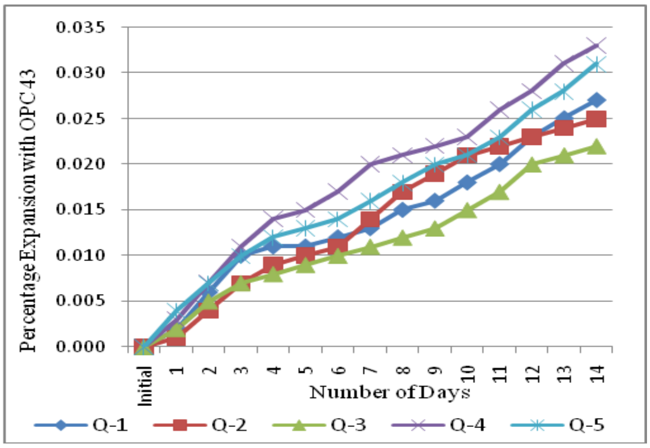

Fig 1: Expansion with OPC 43

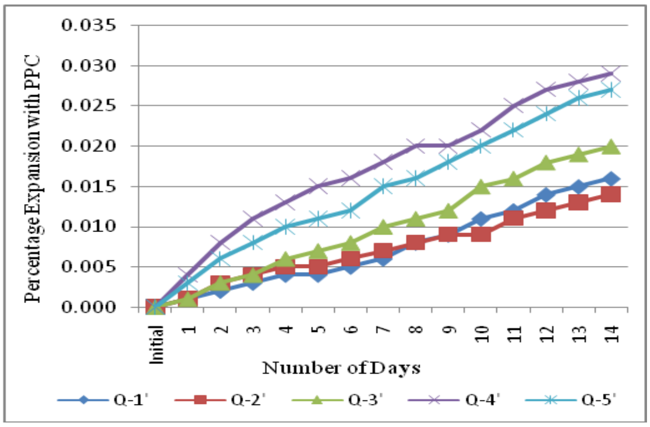

Fig 2: Expansion with PPC

Quarry-1

ASR test for 14-days was conducted on the quarry-1, with both OPC and PPC respectively. The aggregate is found to be innocuous with both the cements. But the uses of PPC with aggregate samples from this quarry arrest the ASR expansion by 40.74% as shown in Fig 3.

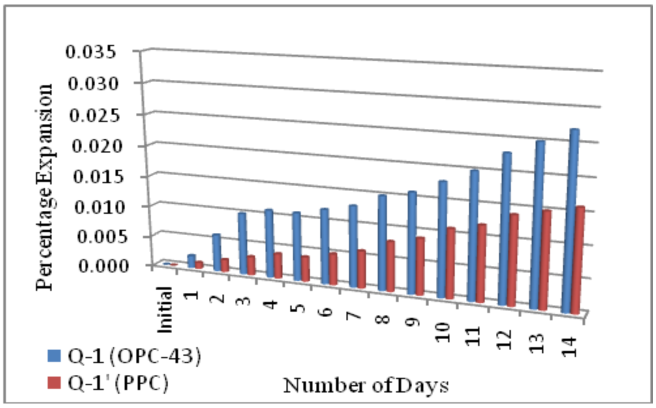

Fig: 3

Quarry-2

ASR test for 14-days was conducted on the quarry-2, with both OPC and PPC respectively. The aggregate is found to be innocuous with both the cements. But the uses of PPC with aggregate samples from this quarry arrest the ASR expansion by 44% as shown in Fig 4.

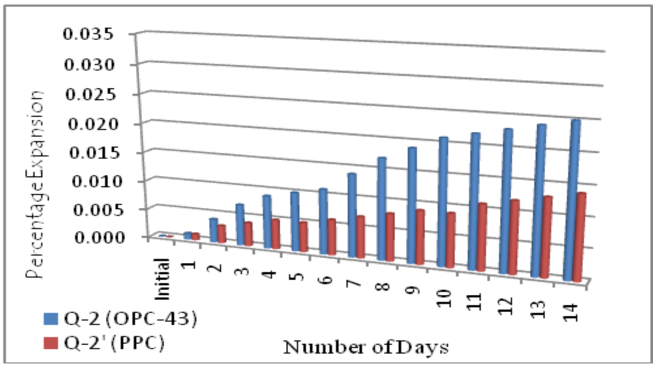

Fig: 4

Quarry-3

ASR test for 14-days was conducted on the quarry-3, with both OPC and PPC respectively. The aggregate is found to be innocuous with both the cements. But the uses of PPC with aggregate samples from this quarry arrest the ASR expansion by 9.09% as shown in Fig 5

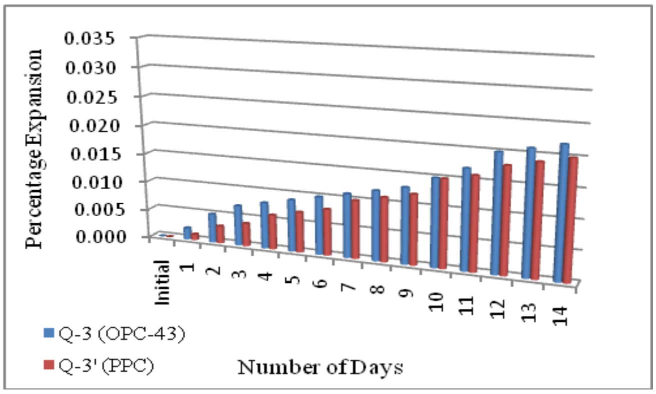

Fig: 5

Quarry-4

ASR test for 14-days was conducted on the quarry-4, with both OPC and PPC respectively. The aggregate is found to be innocuous with both the cements. But the uses of PPC with aggregate samples from this quarry arrest the ASR expansion by 12.12% as shown in Fig 6.

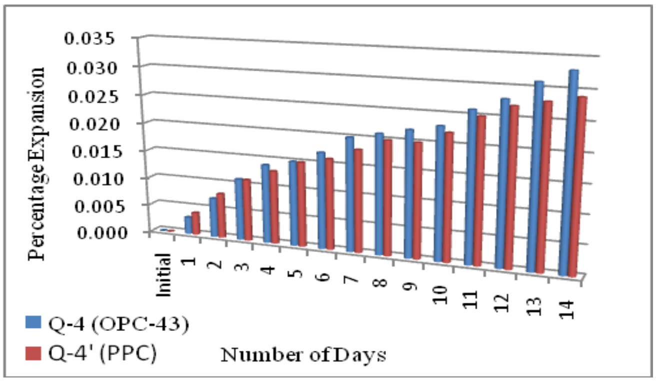

Fig: 6

Quarry-5

ASR test for 14-days was conducted on the quarry-5, with both OPC and PPC respectively. The aggregate is found to be innocuous with both the cements. But the uses of PPC with aggregate samples from this quarry arrest the ASR expansion by 12.90% as shown in Fig 7.

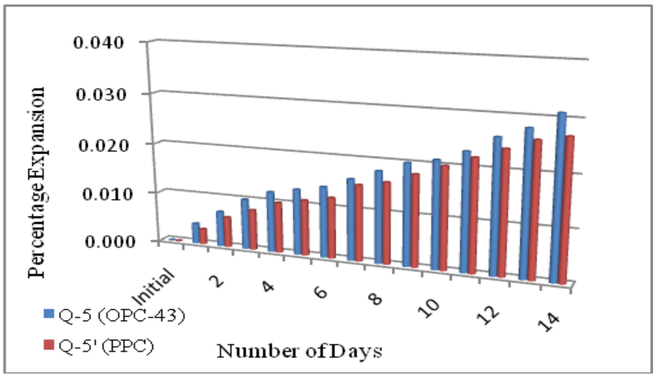

Fig: 7

VI. CONCLUSION

Reactivity of these aggregates and effect of using OPC and PPC on the reactivity of these aggregate have been measured experimentally with the help of accelerated mortar bar test method as per ASTM C 1260 & ASTM C 1567. It has been found by the investigation that the aggregates used for this study are of innocuous nature when tested with OPC and PPC respectively, as the expansion due to ASR is well within the limits, prescribed by the code. The test results reveals that aggregate-PPC combination is better for controlling ASR, as it arrest the expansion produced from the aggregate-OPC combination, by 9 to 44%. Therefore the test results clearly show that PPC is better in controlling expansion due to ASR in comparison to OPC.

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